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FOREST MANAGEMENT EFFECTS ON NESTING HABITAT SELECTED BY EURASIAN BLACK VULTURES (*AEGYPIUS MONACHUS*) IN CENTRAL SPAIN

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ABSTRACT.—We studied two recently established colonies of Eurasian Black Vultures (*Aegypius monachus*). One was located in an abandoned maritime pine *(Pinus pinaster)* plantation formerly used for resin production. The other colony was in a Scots pine (*P. silvestris*) plantation currently used for timber production. The vultures used nest sites with mature trees in forest openings and on steep slopes in the medium-upper portions of mountains. These openings had few roads. Differences in tree density, distance to nearest neighbor's nests, and tolerance to high road density were observed between the nest sites used by the two colonies. Sylvicultural practices in either forests explained differences in nest-site selection between the colonies.

KEY WORDS: *Eurasian Black Vulture;* Aegypius monachus; *forest management; nest-site habitat.*

Efecto del manejo del bosque sobre la selección del hábitat de nidificación del Buitre Negro (*Aegypius monachus*) en España central

RESUMEN.—Se ha estudiado el efecto del manejo del bosque sobre los requerimientos del hábitat de nidificación del Buitre Negro (*Aegypius monachus*) en dos colonias de reciente ocupación. Las colonias se establecieron en dos plantaciones de pino autóctono del Sistema Central español. Ambos bosques se encuentran sometidos a distinto tipo de explotación. En uno de ellos (*Pinus silvestris*) se realiza una explotación maderera y el otro (*Pinus pinaster*) se encuentra en la actualidad en desuso tras haber estado dedicado a la extracción de resina. En ambos bosques los buitres seleccionaron lugares de nidificación con árboles maduros para colocar los nidos, en áreas más desprovistas de vegetación, con una mayor pendiente y situados en el tercio medio-superior de las montañas. En estas áreas también se encontró un menor número de caminos. Se observaron diferencias en la densidad de árboles, en la distancia al nido ocupado más próximo y en la tolerancia a los caminos entre las dos colonias. El diferente uso del bosque explica estas diferencias.

[Traducción Autores]

The Eurasian Black Vulture (*Aegypius monachus*) is a widespread Palearctic species that has suffered a marked decline in Europe in the last century, disappearing from 15 countries (Bijleveld 1974, Tucker and Heath 1994) and experiencing a marked reduction in range and abundance in Greece, Russia, Spain, Ukraine, and also likely in Turkey (Blanco and González 1992, Tucker and Heath 1994). About 200 pairs remained in Spain from 1966–72 (Bernis 1966, Hiraldo 1974). Nevertheless, in the last 20 yr, the population has increased to an estimated 774 pairs in 1990 (González 1990) and 900–1000 pairs in 1992 accounting for between 67–90% of the breeding European population (González in Tucker and Heath 1994). Few studies have focused on the analysis of habitat requirements of this species with only cursory mention of some colonies (Hiraldo 1974, Torres et al. 1980, Bermejo 1990, Donázar 1993).

Loss and alteration of habitat are the most serious threats for raptor populations (Bijleveld 1974, Tucker and Heath 1994). Their large territories, home ranges, and historical persecution by humans have made populations of forest breeding raptors sensitive to forest management and habitat change (Fuller 1996, Niemi and Hanowski 1997). Indeed, declines in Eurasian Black Vulture populations had been previously attributed to alterations of nesting habitats (Hiraldo 1974, Bermejo 1990, Blanco and González 1992, Donázar 1993). The spread of human settlements and intensive agriculture in lowlands and pastures in highlands have caused forest fragmentation and loss of forested areas. Further, intensive forestry has created mosaics of mature stands mixed with successional stands of various ages (e.g., Moorman and Chapman 1996, Niemi and Hanowski 1997).

The Eurasian Black Vulture is closely associated with forests during the breeding season (7–8 mo) and afterwards because it uses trees as roosts and shelters (Bernis 1966, Hiraldo and Donázar 1989). Understanding the interaction between forest management practices and habitat selection by the Eurasian Black Vulture is crucial in planning conservation measures for this threatened species. Furthermore, recent colonization of some areas enables us to determine its habitat requirements because individuals select optimal vacant nesting sites, unlike older colonizations where individuals have been forced to occupy lower quality nesting sites (Brown 1969, Kadmon 1993, Ferrer and Donázar 1996).

STUDY AREA AND METHODS

Two recently established colonies of Eurasian Black Vultures were studied in two pine forests of the Spanish Central Range (Sierra de Guadarrama, 40°30′N). The first colony (colony A) was located in a young maritime pine (*Pinus pinaster*) plantation (forest A) in the province of Madrid (mean elevation = 1150 m, range = 930–1387). This pine species is native of the Spanish Central Range (Mallada 1892). The old pine forest was felled during the Spanish Civil War (1936–39) and the post-war period, and only a few old pines remained. After the war, the area was reforested with a new plantation of pines, making the new forest a mixture of mostly trees about 60-yr old interspersed with few mature trees. Resin extraction was the main use of this forest. The first pair of Eurasian Black Vultures became established in this area in 1985 and, by 1994, the colony consisted of 11 pairs. The second colony (colony B) was in a Scots pine (*Pinus sylvestris*) plantation (forest B) in the province of Segovia (mean elevation = 1600 m, range = 1315–2196). Scots pine is also native of the Spanish Central Range (Galera and Martín 1990). Nowadays, wood exploitation for timber is the main use of this forest. In past years, trees were felled in large areas and newly reforested. Presently, this forest is intensively managed and only individual mature trees are selectively cut leaving some protected areas for natural regeneration. These areas are located in the upper third of the mountains. Vultures became established in this forest in 1989, and, by 1994, the colony consisted of seven pairs. The two colonies are 32 km apart.

We used procedures suggested by Titus and Mosher (1981), Andrew and Mosher (1982), Bosakowski et al. (1992), Donázar et al. (1993), and Moorman and Chapman (1996) to study habitat selection by these vultures. Nest sites were located in the spring of 1994 and plotted on a 1:25 000 topographic map. Characteristics of nest sites were measured in the field during the winter of 1994–95. A nest site was defined as the nest tree plus a circular plot of 25 m radius around it (Titus and Mosher 1981). Vegetation cover within these 25-m radius plots was visually estimated from the center of each subplot (Prodon 1976, Rubio and Carrascal 1994). We also noted the number of trees in different diameter categories and the heights of nest trees. Measurements on other habitat variables (Table 1) studied were obtained from the topographic map.

Random sampling was used to estimate available nest-

Table 1. Variables used to characterize Eurasian Black Vulture nesting and random plots. Variables were measured from a point in the center of the plot.

DT—Stem diameter tree at breast height in cm
HT—Height of tree in m
DNN—Distance of nearest nest of same species in m
SCH—Height of scrubland in plot in m
DTT—Mean distance to three nearest trees in m
PCC—Percent canopy cover in plot
PUC—Percent understory cover in plot
PSC—Percent of scrubland in plot
PPL—Percent of pastureland in plot
PRL—Percent of rockyland in plot
NT1—Number of trees in plot with a stem diameter <15 cm
NT2—Number of trees in plot with a stem diameter 16–30 cm
NT3—Number of trees in plot with a stem diameter 31–50 cm
NT4—Number of trees in plot with a stem diameter >51 cm
NOT—Total number of overstory trees in plot
ATT—Elevation of plots in meters
TII—Topographic irregularity index (number of 20 m contours cut by four 500 m lines from nest tree in the four cardinal compass directions)
NPM—Nest position on mountain by mountain division (1 = upper third, 2 = medium third, and 3 = lower third)
DNV—Distance to nearest village in m
MOR—Meters of paved and unpaved roads within plots with a radius of 500 m from nest trees

Table 2. Sample means ± SD of nest sites and random plots in each colony and forest. ANOVA F values are given for differences between random and nest site plots, between nest sites of each colony, and between random plots of each forest.

	COLONY A				COLONY B			
VAR.	NEST SITES (16)[a]	RANDOM (31)	F (df = 1, 44)	*P*	NEST SITES (13)	RANDOM (37)	F (df = 1, 47)	*P*
DT	57.6 ± 21.0	32.8 ± 10.7	27.5	0.00	62.9 ± 13.5	51.4 ± 12.7	7.6	0.00
HT	13.3 ± 1.7	10.0 ± 2.4	25.1	0.00	13.8 ± 2.2	15.2 ± 3.5	1.1	0.31
DNN	379 ± 205	582 ± 347	5.1	0.02	1362 ± 930	731 ± 478	1.9	0.17
SCH	1.6 ± 0.3	1.8 ± 0.6	1.2	0.28	1.3 ± 1.0	1.8 ± 0.9	2.4	0.26
DTT	8.9 ± 5.6	4.0 ± 2.7	14.1	0.00	7.6 ± 3.1	5.4 ± 5.3	4.3	0.04
PCC	42.0 ± 20.7	64.3 ± 24.5	7.1	0.01	40.6 ± 23.8	62.5 ± 31.4	3.4	0.07
PUC	22.4 ± 19.4	5.5 ± 10.6	20.1	0.00	10.6 ± 12.6	11.9 ± 14.9	0.0	0.90
PSC	73.1 ± 26.7	68.7 ± 28.9	0.5	0.48	35.6 ± 26.4	43.1 ± 29.4	0.2	0.60
PPL	1.3 ± 5.0	19.0 ± 25.6	8.0	0.00	17.8 ± 18.4	24.4 ± 24.7	0.1	0.72
PRL	25.6 ± 24.1	12.3 ± 16.4	3.3	0.07	21.1 ± 25.3	7.6 ± 13.2	2.1	0.15
NT1	12.8 ± 22.6	24.6 ± 24.3	1.5	0.23	20.2 ± 13.6	38.6 ± 56.5	0.0	0.84
NT2	7.8 ± 4.6	23.5 ± 25.9	11.3	0.00	21.6 ± 17.2	25.8 ± 17.4	0.6	0.44
NT3	2.8 ± 2.4	7.8 ± 8.3	6.8	0.01	17.3 ± 10.5	31.4 ± 22.8	2.5	0.12
NT4	0.7 ± 0.9	0.4 ± 0.8	1.1	0.29	11.0 ± 9.9	11.0 ± 10.3	0.1	0.71
NOT	24.3 ± 24.0	57.0 ± 45.5	10.4	0.00	70.1 ± 24.0	107 ± 66	1.1	0.29
ATT	1158 ± 43.7	1135 ± 93.6	1.3	0.26	1761 ± 46.0	1591 ± 42	15.9	0.00
TII	20.6 ± 3.3	14.7 ± 4.7	17.5	0.00	19.3 ± 3.0	15.9 ± 4.8	3.6	0.06
NPM	1.3 ± 0.4	1.8 ± 0.8	6.2	0.01	1.4 ± 0.5	2.1 ± 0.9	6.3	0.02
DNV	1521 ± 542	1774 ± 715	0.7	0.40	4075 ± 869	4317 ± 1393	0.1	0.78
MOR	235 ± 217	501 ± 333	3.8	0.05	133 ± 216	408 ± 425	7.0	0.01

[a] Sample size.

ing habitat. In each colony, random points were plotted on the map with a numbered grid (Titus and Mosher 1981, Hubert 1993). Random points were always included within forested areas, excluding those habitats in which vultures did not nest (e.g., young pine plantations). Once random points were located, the nearest tree was randomly selected as the center of the plot.

To compare nearest-neighbor distances, only nests occupied during the 1994 breeding season were considered. As in other colonies (Bernis 1966, Hiraldo 1983), some pairs did not breed during the year of our study, but the vultures remained close to their nests during the breeding season. For this reason, we considered these nest sites as occupied in order to determine the distance between neighboring nests sites.

We considered all the nests found in the winter of 1994–95, even though some were likely old nesting sites of the same vulture pairs. An analysis of variance (STATISTICA 1993) using planned comparisons was designed to analyze for differences between nests and random plots, and to analyze for differences between habitats. This approach allowed us to include all nest sites in the analysis, avoiding potential pseudoreplication that may have resulted from including nest sites of the same birds. Variables deviating from normality were logarithmic transformed, and percentages were arcsin-transformed.

RESULTS

All the nests found in the two colonies were in pines. In both colonies, we detected a tendency to nest in trees with the greatest diameter (DT, Table 2). Nest trees also were farther from neighboring trees (DTT) and, consequently, had lower canopy covers (PCC). These results indicated a tendency for Eurasian Black Vultures to nest in openings. Percentage and height of scrubland (PSC and SCH, respectively) did not affect nest-site selection.

In terms of nest-site topography, vultures frequently selected areas located in the middle-upper third of the mountains (NPM), with steep slopes (TII, Table 2). Both colonies occurred at high elevations (>1000 m). The minimum elevation (ATT) for a nest was 1090 m (colony A) and the maximum was 1880 m (colony B)

In relation to human disturbance, Eurasian Black Vultures nested in areas with fewer meters of road (MOR) in the surrounding area but the proximity of human habitation (DNV) did not appear

Table 2. Extended.

DIFF. A–B		DIFF. A–B	
NESTS		RANDOM	
F (df = 1, 27)	*P*	F (df = 1.66)	*P*
0.0	0.84	41.3	0.00
0.2	0.69	46.8	0.00
5.9	0.03	1.0	0.32
1.6	0.23	0.0	0.91
0.4	0.54	1.1	0.31
0.8	0.40	0.0	0.98
3.6	0.07	5.5	0.02
8.6	0.00	15.5	0.00
15.6	0.00	3.1	0.09
0.7	0.18	1.5	0.23
1.4	0.25	1.0	0.32
1.9	0.18	0.1	0.72
12.5	0.00	46.9	0.00
19.2	0.00	78.0	0.00
6.3	0.02	13.2	0.00
136.2	0.00	253.3	0.00
0.1	0.78	1.2	0.27
2.3	0.14	1.2	0.29
39.5	0.00	88.1	0.00
5.9	0.03	2.0	0.17

to affect nest-site selection. The closest nest was 800 m from a village.

Forest B had a higher tree density (NT3, NT4, and NOT) with taller (HT) and thicker (DT) trees than those in forest A (Table 2). Forest B also had a smaller percentage of scrubland (PSC), higher elevation, and a greater distance from the closest village.

Nest trees used by vultures in colony A were taller than in random plots but, in colony B, they were not. Furthermore, in colony A, nest sites had a higher proportion of understory cover (PUC) with lower overstory tree density (NOT). There was also a trend to nest in sites with a higher percentage of rocky land (PRL). Vultures in colony B nested in areas with tree densities similar to those of random plots and with higher densities than those of colony A. This was due to the different structural characteristics of the two plantations, plantation B having a higher average tree density. Also, in colony A but not in B, the percentage of pastureland (PPL) was smaller in nest plots than in random plots.

We found a mean distance of 637 m between adjacent nest sites (DNN) of different pairs of vultures in the two colonies. The minimum distance was 150 m (colony A) and the maximum was 2325 m (colony B). The distance between neighboring nests was significantly shorter in colony A (379 m) than in B (1362 m).

Between colony differences in the nest-site selection in regard to DNV were due to the differences in the distance between both plantations, colony A being significantly closer to a village. MOR was similar in both forests but nest plots in colony A had significantly more meters of road than those in colony B.

DISCUSSION

Management practices resulted in a modification of the pine forests we studied including alteration of structural diversity, sizes of trees, and species composition. These effects were more pronounced when forests were used for timber production than when they were used for resin collection. However, the current synthetic elaboration of glue has provoked a decreasing demand of resin in home and international markets causing the end of traditional management for resin extraction (Gil et al. 1990). Furthermore, the damage caused to the trees by the stem cuts results in a low quality of wood timber, which is hardly marketable (Gil et al. 1990). In this management type, the size of tree is less important and tree felling does not occur.

Eurasian Black Vultures, like other large vultures such as the Lappet-faced Vulture (*Torgos tracheliotus*), White-headed Vulture (*Trigonoceps occipitalis*), and White-backed Vulture (*Gyps africanus*), build their nests in the tops of trees (Houston 1974, Mundy 1982, Hustler and Howells 1988). Eurasian Black Vultures build large nests with a diameter of nearly 160 cm and 93 cm in height (Torres et al. 1980). These large nests frequently fall to the ground because of their weight (Bernis 1966). Most nest trees used in both colonies were older than 60 yr, indicating that vultures prefer mature trees in which to build their nests. This preference is probably due to the fact that large trees are necessary to hold their nests. Because there were only a few mature trees in colony A and these were distributed homogeneously on the upper and middle third of the mountain, their preference for older trees restricted the distribution of vultures in forest

A. In colony B, vultures used old trees restricted to the middle-upper third of the mountains where the forest had been protected from timber harvesting. There, trees located next to the crest of mountains are more exposed to hard climatic conditions and were shorter than expected in relation to the diameter of the stem.

Habitat around nests was characterized by open areas with pronounced slopes. Hiraldo and Donázar (1989) found Eurasian Black Vultures breeding in steep areas increase the amount of time available for searching for food and vultures breeding in plains are more dependent on thermals for flying (Hiraldo and Donázar 1989). Open areas with steep slopes may also provide greater visibility of predators, favor an easy nest access, and limit human disturbance (Titus and Mosher, 1981, Speiser and Bosakowski 1988, Donázar et al. 1993, Moorman and Chapman 1996). In colony B, vultures had fewer options to select nest sites because mature trees were only in protected areas. The larger percentage of pastureland in the random plots in colony A was due to the fact that a higher proportion of habitat was devoted to cattle grazing on the lower and middle thirds of the mountains.

The mean distance to the nearest-neighbor nest in colony A (379 m) was within the range (175–521 m) described by Hiraldo (1974), and significantly less than distances between random plots indicating a tendency for vultures to aggregate in this forest. For colony B this distance is much greater and did not differ from random plots. In forest B, vultures are forced to nest in protected areas while the apparently more natural conditions in forest A allowed them to select optimal nesting sites.

Human disturbance has been suggested as the main factor limiting Eurasian Black Vulture productivity (Garzón 1973, Hiraldo 1977, Bermejo 1990). Vultures in our study seemed to avoid human activity by nesting in areas with less paved and unpaved roads. There were no significant differences in road density between both forests, however, nesting areas in colony A contained a higher number of roads. This higher tolerance to roads was associated with the large number of old and abandoned roads left after resin extraction ended in the forest. The distance to the nearest village did not seem to be a factor that influenced nest-site selection, probably because the village was far enough away to be tolerated by this species.

This study demonstrates differences in habitat selection of Eurasian Black Vultures between areas subjected to different forestry practices. In forest A, where resin collection was carried out until 1985, traditional management afforded a relatively natural structure of the forest with few modifications in size class distribution and tree density. After the end of sylvicultural management, rapid occupation by vultures and homogeneous nest distribution was possible in this forest. In contrast, sylvicultural management for pine harvesting in forest B resulted in a greater modification of the size class distribution and tree density. Such forest management has forced the vultures to nest in protected areas located in the upper third of the mountains where there are mature trees resulting in a less homogeneous distribution of this vulture colony.

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